EXECUTIVE SUMMARY

Background

The Water Supply and Treatment Division of the City and County of San Francisco has had two previous studies conducted in response to Proposition H. One study, conducted by HDR Engineering and Newcomb Anderson Associates, was a preliminary energy assessment of the Baden Pumping Station, Crystal Springs Pumping Station, and the Harry Tracy Water Treatment Plant. The purpose of the preliminary assessment described above was to identify cost-effective measures that could reduce operating costs. The second study identified and evaluated improvements to the ozone system at the Harry Tracy Water Treatment Plant and was performed by Olivia Chen Consultants. Upon reviewing the previous reports, the City and County of San Francisco initiated this study to provide the following:

- An energy assessment of the Harry Tracy Water Treatment Plant.
- A lighting analysis for the Harry Tracy Water Treatment Plant.
- A feasibility study of measures previously identified for the Baden Pumping Station.
- A review and summary of the Olivia Chen ozone system improvements report.

Table 1-1 is a snapshot of the 1999 energy use at the Harry Tracy WTP.

Table 1-1 Harry Tracy WTP 1999 Energy Snapshot

Plant Flow	20,587 Mgal
Average Daily Flow	56.4 mgd
Annual Energy Cost	$556,707
Annual Energy Consumption	9,199,755 kWh
Billing Electrical Demand	1,280 – 2,410 kW
Average Energy Cost	6.05 ¢/kWh
Specific Unit Electrical Consumption	446 kWh/Mgal
Total Estimated Energy Savings	621,960 kWh
Total Estimated Cost Savings (ECMs HT-1 through 7)	$45,800
Percent Cost Reduction	8%

Harry Tracy WTP Energy Assessment

In 1999, the treatment plant paid $556,707for 9,199,755 kWh of electricity needed to treat 20,587 million gallons. This equates to an average of 6.05 ¢/kWh and a specific energy consumption of 446 kWh/Mgal. Monthly electrical (billing) demand ranged from 1,280 kW to a maximum of 2,410 kW. The influent pumping station consumes the most power followed by the ozone system.

Three energy conservation measures (ECMs) for the raw water pumping station were evaluated to reduce energy consumption. One measure is recommended for implementation and is estimated to save approximately $45,800 annually. This measure was selected based on simplicity, low cost, and with consideration for the upcoming plant expansion. One ECM was developed for the ozone system. The measures are summarized in Table 1-2.

TABLE 1.2 SUMMARY OF MEASURES - Harry Tracy WTP Energy Assessment

ECM Description		Electric Demand Saved (kW)	Electric Energy Savings (kWh/yr)	Annual Cost Savings ($/yr)	Estimated Project Cost ($)	Net Life Cycle Benefit ($)	Simple Payback Period (yrs)	Potential PG&E Rebates	Recommended
HT-1	Trim the impeller of one 46 mgd pump	284	621,960	$45,800	$8,500	$179,300	0.2	55,976	YES
IHT-2	Install a VFD on one 46 mgd pump	284	621,960	$45,800	$240,000	($52,200)	5.2	55,976	NO
HT-3	Install one new 46 mgd pump	272	595,680	$43,000	$350,000	($173,700)	7.5	53,611	NO
HT-4	Modify Ozone Air Compress or	17	148,920		$18,750	$58,125	1.9	55,926	YES
TOTAL			**770,880**	**$45,800**	**$27,250**	**$237,425**	**2.1**	**111,902**	

Harry Tracy WTP Lighting Analysis

At the time of the survey, it was learned that several portions of the Main Building were scheduled for renovation. The scope of the project includes replacement lighting in much of the project area. Therefore, the estimate of potential savings is based on lighting retrofit in the areas other than where the planned renovation involves replacement of the existing lighting fixtures. Three measure from the lighting analysis are recommended to save over $18,500 annually. This represents a 3 percent reduction in energy costs. The measures are summarized in Table 1-3.

TABLE 1.3 SUMMARY OF MEASURES - Harry Tracy WTP Lighting Analysis

ECM Description	Electric Demand Saved (kW)	Electric Energy Savings (kWh/yr)	Annual Cost Savings ($/yr)	Estimated Project Cost ($)	Net Life Cycle Benefit ($)	Simple Payback Period (yrs)	Potential PG&E Rebates	Recommended
HT-5 Convert Mercury Vapor Fixtures to High-Pressure Sodium Sources	47	267,624	$17,900	$51,143	$112,180	2.9	$24,086	YES
HT-6 Install Occupancy Sensors for Lighting Control	0	5,629	$380	$1,500	$775	3.9	$506	YES
HT-7 Adjust, Replace, or Install Photocells for Lighting Control	0	3,897	$260	$1,300	$245	5	$350	YES
TOTAL	**47**	**277,150**	**$18,540**	**$53,943**	**$113,200**	**2.9**	**$24,942**	

A total of five ECMs are recommended for implementation. These are estimated to save $64,340 annually. This represents an 11 percent reduction in energy costs for the treatment plant.

Baden Pumping Station Feasibility Study

The feasibility study for the Baden Pumping Station provides a more detailed analysis of energy cost savings measures that were identified in the preliminary energy audit of the site (Newcomb Anderson Report _____). It provides more accurate estimates of the costs and savings associated with the recommended measures. These estimates are provided to support the Division's maintenance and capital planning process. From October 1998 through September 1999, the Baden Pumping Station operated a total of 803 hours. During this time the City paid $287,133 for 1,364,825 kWh of electricity used by the station. This averages to 21 ¢/kWh. Table 1-4 is a snapshot of the 1998/99 energy use at the Baden Pumping Station.

Table 1-4 Baden Pumping Station 1998/99 Energy Snapshot

Annual Energy Cost	$287,133
Annual Energy Consumption	1,364,825 kWh
Max. Electrical Demand	798 - 1858kW
Average Energy Cost	6.05 ¢/kWh
Total Estimated Demand Shifted	1,570 kWh
Total Estimated Savings (ECMs B1-3)	$97,900
Cost Savings	34%

Table 1.5 is a summary of the measures analyzed, which are estimated to save nearly $98,000 annually. Two of the recommendations are no-cost modifications to the operation of the pumps. An analysis of the effect of these modifications indicates that adequate performance will be maintained.

TABLE 1.5 SUMMARY of MEASURES - Baden Pumping Station

ECM Description	Electric Energy Savings (kWh/yr)	Electric Demand Shifted (kW)	Annual Cost Savings[1] ($/yr)	Estimated Project Cost ($)	Net Life Cycle Benefit[2] ($)	Simple Payback Period[3] (yrs)
B-1 Pump Off-peak	0	1,570	$51,200	$0	$92,600	Immediate
B-2 Install Transformer and Receive Power at Primary Voltage[4]	0	0	$28,000	Not Estimated	$50,900	
B-3 Operate Emergency Generator to Avoid Peak Demand Charges[5]	0	785	$18,700	$0	$33,800	Immediate
TOTAL	**0**	**1,570**	**$97,900**	**$0**	**$126,400**	

1 Annual savings are calculated at current rates. Electricity rates are expected to decline by 20% to 25% in the next 3 to 4 years when the Customer Transition Charge expires.
2 Net Life Cycle Benefit = Present Value of Annual Savings – Project Cost. A measured life of 2 years is assumed, corresponding to the period until the Customer Transition Charge is expected to expire and rates are expected to decline.
3 Simple Payback Period = Estimated Project Cost/Annual Monetary Savings.
4 Savings are calculated assuming the off-peak pumping recommendation is implemented.
5 Savings are calculated assuming unavoidable peak period operation is required for 2 months during the year. Existing E20S rates are used due to the uncertainty of implementing the recommendation to install a transformer and receive power under E20P rates.

Review of Olivia Chen Consultants Report

HDR was asked to review the results of the Olivia Chen Consultants (OCC) report dated October 1998 to determine if 1) a Phase 2 energy monitoring program is practical and 2) which energy optimization ideas from the report (or others) could be implemented. The ozone system energy usage represents approximately 20 percent of the plant power costs. We estimate the ozone system energy costs to be approximately $120,000 per year. The existing system is obsolete and total optimization probably cannot produce more than $20,000 annually in savings. (See ECM HT-4 for the most significant optimization idea). We concur with virtually all of the energy related findings of the OCC report. We are not convinced that a Phase 2 energy monitoring program will be cost effective unless all data can be acquired automatically. The potential savings is small. It would be much more practical to monitor power performance of the energy intensive raw water pumping station.

INTRODUCTION

Purpose

The purpose of this study is to support the PUC in its efforts to reduce costs. This report evaluates recommendations for the Harry Tracy Water Treatment Plant and the Baden Pumping Station that aim at reducing electrical costs, which comprises a large portion of the operating costs.

Background

In response to Proposition H, the San Francisco's voter-approved measure to freeze water and wastewater rates for five years, the PUC authorized preliminary energy studies at the Harry Tracy Water Treatment Plant, the Crystal Springs Pumping Station, and the Baden Pumping Station. In follow-up to those reports, the Bureau of Energy Conservation (BEC) and Water Supply and Treatment (WST) Division of the City and County of San Francisco initiated this study to expand on the previous reports and to further evaluate some of the measures identified therein.

This report was conducted by HDR Engineering and Newcomb Anderson Associates. The report is funded by the Electric Power Research Institute (EPRI) on behalf of the California Energy Commission (CEC) and the Hetch Hetchy Bureau of Energy Conservation (HH/BEC).

Scope

The scope of this report is limited in scope to the Baden Pumping Station and the Harry Tracy Water Treatment Plant. It includes the following four items:

- An energy assessment of the Harry Tracy Water Treatment Plant.
- A lighting analysis for the Harry Tracy Water Treatment Plant.
- A feasibility study of measures previously identified for the Baden Pumping Station.
- A review and summary of the Olivia Chen Consultants' Harry Tracy ozone system improvements report.

HDR Engineering evaluated energy conservation measures for the Harry Tracy Water Treatment Plant and conducted the review of the Olivia Chen Consultants' report. Work was performed by Ken Henderson and Dave Reardon. Newcomb Anderson Associates conducted the feasibility study for measures at the Baden Pumping Station and the lighting audit at the Harry Tracy Water Treatment Plant. Work was managed by Mary Bryan.

Accuracy

This report is based on a "walk through" evaluation of the facilities. It is a planning level document intended to identify energy conservation measures (ECMs) and electrotechnologies that could benefit plant operations. The recommended projects should be implemented only after conducting pre-design/design level analysis, which is beyond the scope of this report. The accuracy of all cost and savings estimates are ±25 percent. Construction cost estimates are made for each idea individually. The total for engineering and construction services can vary depending on the combination of ideas selected for installation, the amount of instrumentation and control interfaces desired, deviation from standard equipment configurations, the schedule of construction, and the level of bidding and construction services requested.

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HARRY TRACY WATER TREATMENT PLANT

Description

The Harry Tracy Water Treatment Plant receives water from the Hetch Hetchy Water System. The raw water pumping station has six horizontal split-case pumps that lift water from the San Andreas Reservoir to the treatment plant. Three of the pumps are 900 hp constant speed units rated for 32,000 gpm (46 mgd). The other three pumps are 300 hp variable speed units rated for 10,000 gpm (14.4 mgd). The station was designed for 98 feet of head to accommodate high flows with low water levels in the reservoir. However, under normal conditions, the pumps operate at approximately 50 feet of head. As a result, the constant speed pumps need to be throttled to prevent them from running too far right on their curve. The plant can operate with the smaller pumps during the winter but often use one or more of the larger pumps to meet demand in the summer. Throttling the large pumps is inefficient and presents an opportunity to reduce pumping costs.

Water is treated with ozone prior to filtration. A schematic of the Harry Tracy WTP is presented in Figure 3-1.

Historical Energy Use

From June 1998 through May 1999, the plant paid $537,524 for 8,977,474 kWh of electricity. This equates to an average of 5.99 ¢/kWh. Electrical power is fed to the station from the Water Treatment Plant. No historical data for the pumping station was available. It is estimated that the pumping station uses approximately 74 percent of the total power at the plant.

The plant purchases electrical power from Pacific Gas & Electric Company under rate schedule E-20T. PG&E has two primary charges for electrical power under this schedule. The first is for *demand*, which is the power supplied by the electric utility measured in kilowatts (kW). The second, *energy*, is the quantity of power used measured in kilowatt hours (kWh). Rate Schedule E-20T is a Time-of-Use (TOU) rate schedule that bills for both energy and demand based on the time of day it is used.

We recommend that the City take advantage of PG&E's 2000 rebate program. The Standard Performance Contract can provide up to $0.09/kWh saved the first year of operation for retrofits. Contact your PG&E representative. Application forms are available on the internet at *www.pge.com*.

Energy Conservation Measures (ECMs)

HDR developed four process ECMs. Lighting ECMs are presented in Section 4. The ECMs listed below were developed from information collected at the site visit, the pump curves, and from evaluation of historical plant data. Unless otherwise noted, savings for the ECMs was determined using costs under the E20T rate schedule. Calculations are in Appendix A.

ECM HT-1	Trim the impeller of one 46 mgd pump.
ECM HT-2	Install a VFD on one 46 mgd pump.
ECM HT-3	Install a new 46 mgd pump.
ECM HT-4	Install VFD on ozone air compressor.

ECM HT-1 SUMMARY SHEET

TRIM THE IMPELLER OF ONE 46 MGD PUMP

Existing Conditions—

The plant's raw water pumps are design for 98' TDH. Pressure gage readings at the pumps indicate a TDH of approximately 50' at 45 mgd.The 900 hp pumps run to the right of their curves and are therefore throttled with a control valve on the pump discharge to control flow.

Proposed Change—

Have the manufacturer trim the impeller of one pump to change its design point to 32,000 gpm @ 60' TDH. Check with the pump manufacturer to verify performance prior to making the change. Manufacturer's records indicate the plant already has a backup impeller that could be used to revert back.

Benefit or Effect on Operations—

Although modifying the impeller is a low cost effective method to alter the design point, improve efficiency, and reduce operating costs, it is not as flexible as VFDs. However, the plant owns a backup impeller that could be used should future conditions dictate. Although running the motor at half load will lower the power factor, it will have negligible effect on the motor's efficiency . PG&E bills 0.6% for each percentage point the power factor falls below 85%. A 900 hp motor half loaded has a power factor of approximately ±85%. Penalty for power factor will be minor.

Cost Analysis—

Demand Savings:	284 kW
Energy Savings:	621,960 kWh
Annual Operating Cost Savings:	$45,800
Capital Cost for Changes:	$8,500
Net Life Cycle Benefit*:	$179,300
Simple Payback:	0.2 years
Recommended:	YES

* Based on 5 year life cycle at 7%.

ECM HT-2 SUMMARY SHEET

INSTALL A VFD ON ONE 46 MGD PUMP

Existing Conditions—
See ECM HT-1.

Proposed Change—
Install a VFD on one large pump. Run at reduced speed.

Benefit or Effect on Operations—
A VFD has greater flexibility than changing the impeller. Space needed in the MCC room raises the cost. Might not be needed after expansion of plant.

Cost Analysis—

Demand Savings:	286 kW
Energy Savings:	621,960 kWh
Annual Operating Cost Savings:	$45,800
Capital Cost for Changes:	$240,000
Net Life Cycle Benefit*:	($52,000)
Simple Payback:	5.2 years
Recommended:	NO, See ECM 1.

* based on 5 year life cycle at 7%.

ECM HT-3 SUMMARY SHEET

INSTALL ONE NEW 46 MGD PUMP

Existing Conditions—
See ECM HT-1.

Proposed Change—
Install a new constant speed pump rated for 32,000 gpm at 60' TDH.

Benefit or Effect on Operations—
This would produce the same flow at lower head, saving energy. Space needed in the MCC room raises the cost. Might not be needed after expansion of plant.

Cost Analysis—

Demand Savings:	272 kW
Energy Savings:	595,680 kWh
Annual Operating Cost Savings:	$43,000
Capital Cost for Changes:	$350,000
Net Life Cycle Benefit*:	($173,700)
Simple Payback:	7.5 year
Recommended:	NO, See ECM 1.

* Based on 5 year life cycle at 7%.

ECM HT-4 SUMMARY SHEET

MODIFY OZONE AIR COMPRESSOR

Existing Conditions—

Rotary screw compressors operate On/Standby. On - air is compressed and delivered to receiver. Standby - no air is delivered. Existing pressure is 27 to 32 psi. On mode is 34 kW, Standby mode is 17 kW.

Proposed Change—

Install a VFD on one unit and lower pressure to 15 psi (see OCC report).

Benefit or Effect on Operation—

17 kW savings continuous. No effect on operations.

Cost Analysis—

Demand Savings:	17 kW
Energy Savings:	148,920 kWh/yr
Capitol Cost:	$18,750 for one compressor
Net Life Cycle Benefit:	$58,125
Simple Payback:	1.9 years
Recommended:	YES

HARRY TRACY WTP LIGHTING ANALYSIS

Lighting System Description

According to guidelines published by the Illuminating Engineering Society (IES), the recommended light levels for offices range between 30 and 50 footcandles (fc). Recommended light levels for hallways and other service spaces range between 10 and 20 fc. Projects described in this report are designed to maintain those levels. Illuminance levels will typically increase by approximately 15% in areas where conversion from T-12 to T-8 lamps has been recommended. However, some reduction in light levels should be anticipated for areas where delamping has been recommended.

The buildings are illuminated primarily by fluorescent lighting. Fixtures are typically surface-mounted or recessed into a suspended ceiling. These fixtures are primarily 4-foot fixtures with two, three, or four F40 T-12 lamps. Ballasts for these fixtures primarily contain magnetic components. We estimate that approximately 5% of the existing fluorescent fixtures in the surveyed areas have T-8 lamps and electronic ballasts.

A significant number of fixtures contain high pressure sodium lamps. These fixtures are located in tunnels, stairwells, and exterior locations. The fluoride area of the Chemical Storage Building is illuminated by metal halide lighting fixtures. Roadway lighting is provided by mercury vapor sources.

Incandescent lighting is used for Exit sign illumination and in storage and service spaces. Exterior fixtures located on the perimeter of the Main building and in the Filter Bay areas contain incandescent lamps.

Interior lighting typically operates between 10 and 24 hours per day depending on the location and use of each space. During the site audit, lighting fixtures were observed to be operating in occupied spaces and turned off in some vacant spaces. Our calculations are based on shorter operating hours for lighting systems in spaces where use patterns indicate that the area is not occupied 24 hours per day.

Exterior lighting is controlled by a combination of photocells and manual controls, although some fixtures were noted to be operating during the day.

Energy Conservation Measures

At the time of the survey, it was learned that several portions of the Main Building were scheduled for renovation. The affected area includes the electronic shop, the carpenter's shop, and Q-rep training. The likelihood of this project being implemented was confirmed in follow-up conversations with the Bureau of Energy Conservation. Facility personnel supplied a drawing that indicates that the scope of the project includes replacement lighting in much of the project area.

The estimate of potential savings has been calculated on the basis that no lighting retrofit will be performed in the areas where the planned renovation involves replacement of the existing lighting fixtures.

We have identified the following measures to reduce the connected lighting load and therefore achieving lighting energy savings whenever fixtures are operated. A list of recommended projects, by area, is provided in the "Load Reduction Projects" calculations in the Appendix A. We do not anticipate any significant operational changes, maintenance costs, or salvage values as a result of this project.

ECM HT-5	Convert Mercury Vapor Fixtures to High-Pressure Sodium Sources
ECM HT-6	Adjust, Replace, or Install Photocells for Lighting Control
ECM HT-7	Adjust, Replace, or Install Photocells for Lighting Control

ECM HT-5 SUMMARY SHEET

CONVERT MERCURY VAPOR FIXTURES TO HIGH-PRESSURE SODIUM SOURCES

Existing Conditions—

Roadway lighting is provided by pole-mounted "cobra head" fixtures that contain 400W Mercury Vapor (MV) lamps. Mercury Vapor light sources are inefficient compared to other available light sources, such as High Pressure Sodium (HPS).

Proposed Change—

Remove the 400W MV lamp and associated ballast and socket assembly from each roadway fixture and installing a 250W HPS lamp and hard-wired retrofit assembly in its place.

Benefit or Effect on Operations—

Lighting retrofits will not effect plant operations. Area lighting will change from bluish-green to yellow. These retrofits will provide illumination comparable to the existing case.

Cost Analysis—

Demand Savings:	47.3 kW
Energy Savings:	267,624 kWh
Annual Operating Cost Savings:	$17,900
Capital Cost for Changes:	$51,143
Net Lifecycle Benefit	$112,180
Simple Payback:	2.9 year
Recommended:	YES

ECM HT-6 SUMMARY SHEET

INSTALL OCCUPANCY SENSORS FOR LIGHTING CONTROL

Existing Conditions—

During the site survey, lighting was observed to be operating whether or not a given area was occupied. Lighting is often switched on when an area is first occupied and switched off by janitorial staff at the end of the shift.

Proposed Change—

Install occupant sensors in selected spaces to reduce lighting operation during unoccupied periods. Use sensors that detect occupancy using ultrasonic or infrared wave technologies.

Benefit or Effect on Operations—

Changes to lighting controls will not effect plant operations. Maintain sufficient lighting level for safety. Do not use sensors in areas that could create unsafe conditions during maintenance activities.

Cost Analysis—

Demand Savings:	0 kW
Energy Savings:	5,629 kWh
Annual Operating Cost Savings:	$380
Capital Cost for Changes:	$1,500
Net Lifecycle Benefit	$775
Simple Payback:	3.9 years
Recommended:	YES

ECM HT-7 SUMMARY SHEET

ADJUST, REPLACE, OR INSTALL PHOTOCELLS FOR LIGHTING CONTROL

Existing Conditions—

Some of the exterior lighting was observed to be operating during the day.

Proposed Change—

Inspect existing photocells for proper function, and adjust or replace defective units.

Benefit or Effect on Operations—

Changes to lighting controls will not effect plant operations.

Cost Analysis—

Demand Savings:	0 kW
Energy Savings:	3,897 kWh
Annual Operating Cost Savings:	$260
Capital Cost for Changes:	$1,300
Net Lifecycle Benefit	$245
Simple Payback:	5 years
Recommended:	YES

DISCUSSION

Convert Mercury Vapor Fixtures to High-Pressure Sodium Sources

HPS lighting is between two and three times as efficient as MV lighting. The standard rated life of both sources is approximately 24,000 hours. HPS, a standard light source for street lighting, provides illumination with a yellowish tint in comparison to the blue-green color associated with MV. We recommend HPS lighting as a retrofit light source for the existing MV streetlights.

Install Occupancy Sensors for Lighting Control

During the site survey, lighting was observed to be operating whether or not a given area was occupied. These observations were supported during discussions with site personnel. In many cases, office area lighting is switched on when an area is first occupied and switched off by janitorial staff at the end of the shift.

We recommend installing occupant sensors in selected spaces to reduce lighting operation during unoccupied periods. Sensors detect occupancy using ultrasonic or infrared wave technologies. Lighting systems are automatically enabled when an occupant is detected and turned off after an area has been vacant for a preset period.

Typical spaces recommended for the installation of occupancy sensors include offices, conference rooms, and utility spaces. Occupant sensors may be mounted on the wall at existing switch locations or mounted on the ceiling. Ceiling-mounted sensors require the use of low voltage switching relays. In general, we recommend using wall switch replacement sensors for single occupant offices and other small rooms. We also recommend installing ceiling-mounted sensors in locations without local switching, where the existing wall switches are not in the line-of-sight of the main work area, and in large spaces. We have included an estimate of the required number of wall and ceiling sensors; however, the actual specification of sensor models and placement is typically determined during the design process.

We anticipate a 30% reduction in lighting operating hours with this measure for affected areas. Refer to the "Reduction in Lighting Operating Hours" section in the Appendix for specific locations.

Adjust, Replace, or Install Photocells for Lighting Control

Some of the exterior lighting was observed to be operating during daylight hours. We recommend that existing photocells be inspected for proper function, and that they be adjusted or replaced when found to be defective. In some cases, new photocells may be required. Based on observed patterns of use, we estimate that this project will reduce the duration of lighting operation of those fixtures observed to be operating during the day by 50%.

Replace Magnetic Ballasts and T-12 Lamps with Electronic Ballasts and T-8 Lamps

Some of the fixtures in this facility have already been retrofitted with solid-state (electronic) ballasts and T-8 lamps. The remaining fluorescent lighting fixtures consist of a fixture housing, standard magnetic (core and coil) ballasts, and 4-ft. long, T-12 sized (1-1/2" diameter), rapid start, F40, bi-pin lamps. This type of system has been an industry standard for several decades. A reduction in the connected lighting load can be achieved while providing light levels comparable to the existing ones.

Solid state ballasts operate fluorescent lamps more efficiently and generate less heat than conventional magnetic ballasts. They are typically quieter and produce less lamp flicker than magnetic ballasts. Solid state ballasts are available with a range of power consumption and light output options that permits post-retrofit light levels to be tailored to lighting requirements. Dimming solid state ballasts are also available.

Another improved technology is the tri-phosphor T-8 lamp. T-8 lamps are physically similar to conventional T-12 lamps, except that they have a smaller diameter (1"). T-8 lamps are more efficient than T-12 lamps, due to optical, thermal, and electrical operating characteristics. They also provide better color rendition. A combination of T-8 lamps and electronic ballasts has a system efficacy of about 76 lumens per watt compared to 53 lumens per watt for a conventional system.

In general, we recommend replacing existing magnetic ballasts with low power (reduced output) solid state ballasts and T-12 lamps with T-8 lamps on a one-for-one basis in fluorescent fixtures. We have recommended removing lamps from areas subject to both a high lighting power density and excessive light levels. The light levels will increase somewhat except in areas recommended for delamping. We anticipate the resulting light levels will meet or exceed the recommended illuminance levels established by IES standards as appropriate for the indicated areas.

Convert Incandescent Fixtures to Compact Fluorescent Sources

Utility rooms, rest rooms, and perimeter building exterior locations are illuminated with incandescent fixtures. These fixtures typically contain either 52W or 135W incandescent lamps. Incandescent light sources are inefficient compared to other available light sources, such as fluorescent.

Compact fluorescent lighting is about four times as efficient as incandescent lighting. The standard rated life for compact fluorescent lamps is 10,000 hours, while incandescent lamp life ranges from 750 to about 2,000 hours. We recommend compact fluorescent lighting as a retrofit or replacement light source for the existing incandescent light source.

We recommend removing the incandescent lamps in existing fixtures and installing a screw-based compact fluorescent lamp-ballast assembly. The recommended retrofit generally involves replacing 52W incandescent lamps with 15W compact fluorescent lamps and replacing 135W incandescent lamps with 25W compact fluorescent lamps. These retrofits will provide illumination comparable to the existing case.

Replace Incandescent Exit Signs with LED Exit Signs

Incandescent Exit signs are inefficient compared to LED sources. We recommend LED technology for replacement of incandescent lighting because of its high efficiency and long life. Most LED Exit signs are warranted for 25 years.

Replace Filter Gallery Incandescent Lighting with New Metal Halide Fixtures

The Filter Gallery areas are illuminated with PAR-type incandescent flood lamps. The main purpose of the lighting is to illuminate the Filter Gallery walls for inspection and washing. Incandescent light sources are inefficient compared to other available light sources, such as metal halide.

Metal halide lighting is about four times as efficient as incandescent lighting. Metal halide also provides a white colored light suitable for inspection activities. The standard rated life of metal halide lamps is about 10,000 hours, while incandescent lamp life ranges from 750 to about 2,000 hours. We recommend new 75W metal halide flood fixtures to replace the 150W incandescent flood lighting that serves the Filter Gallery areas. This measure will increase illumination levels in the Filter Gallery area.

BADEN PUMPING STATION FEASIBILITY ANALYSIS

PREFACE

Newcomb Anderson Associates of San Francisco, California, prepared this document for the Hetch Hetchy Bureau of Energy Conservation (HH/BEC) of the City and County of San Francisco. The Newcomb Anderson Associates Project Manager is Mary M. Bryan, P.E. The author of this report is Mary M. Bryan, P.E. The report was reviewed for technical quality by Michael K. J. Anderson, P.E., and edited by Zaafar Hasnain. Michelle L. Ryti and Ginny P. Wolf provided clerical support.

Hetch Hetchy/Bureau of Energy Conservation is working with all three water divisions to identify energy cost savings opportunities. This work is intended to help the divisions meet their operational requirements within the spending limits imposed by Proposition H, San Francisco's voter-approved rate freeze for water and wastewater rates.

Energy costs are the divisions' second highest operating cost, after salaries. Reductions in energy costs would allow the division to direct scarce resources to other needs or to leverage capital funds for system upkeep and upgrades. In addition, energy efficiency work provides environmental benefits and can provide maintenance, safety, and use benefits as well.

The energy cost reduction study, though funded by HH/BEC, has relied on the considerable expertise and support of the operating staff and management of the San Francisco Water Supply and Treatment Division. The effort is part of the PUC's wider efforts to reduce operating costs throughout the water and wastewater divisions.

This report summarizes the feasibility energy study at the Baden Pumping Station operated by the San Francisco Public Utilities Commission (PUC) Water Supply and Treatment Division. It provides a more detailed analysis of energy cost savings measures that were identified in the preliminary energy audit of the site. The primary purpose of this feasibility study is to provide accurate estimates of the costs and savings associated with the recommended measures. These estimates are provided to support the Division's maintenance and capital planning process.

SUMMARY

The purpose of the City and County of San Francisco Water Supply and Treatment Division (WS&T) is to ensure that fresh, clean water is distributed to its 2.3 million customers in the San Francisco Bay Area. WS&T delivers approximately 245 million gallons (MG) of water to its customers on an average day. During periods of high demand, up to 365 million gallons per day (MGD) of water are delivered. In order to meet this demand, WS&T operates and maintains a variety of facilities, including water filtration plants, disinfection stations, pipelines, pump stations, equipment maintenance facilities, and office space. Filtration plants operate 24 hours per day, seven days per week and maintenance staff are available at all hours to respond to emergencies.

A preliminary energy audit was conducted at three WS&T division facilities: the Harry Tracy Water Treatment Plant, the Crystal Springs Pumping Station, and the Baden Pumping Station. The purpose of the preliminary energy audit was to identify cost-effective measures that can be developed into energy efficiency retrofit projects through additional detailed engineering analysis and design. After review of the preliminary reports, BEC and WST staff decided to proceed with a feasibility audit of the Baden Pumping Station. This report is a result of the feasibility audit.

The Baden Pumping Station incurs approximately $290,000 per year in electricity costs. The results of the feasibility audit show a potential for reducing energy costs at this site by 35%, which corresponds to an annual savings of $100,200 at current rates. This can be achieved through the implementation of operational changes. These operational changes can be implemented at no cost, so they have an immediate payback period. The economic analysis of the identified measures is provided in the appendices. A summary of the projects is in Table 5-1.

Several of these recommendations involve modifications to the operation of the pumps and include new pumping strategies. An analysis of the effect of these modifications indicates that adequate performance will be maintained. This was confirmed with discussions with operating personnel.

TABLE 5.1 SUMMARY of PROJECTS - Baden Pumping Station

ECM	**Electric Energy Savings** (kWh/yr)	**Electric Demand Shifted** (kW/mo)	**Annual Cost Savings**[1] ($/yr)	**Estimated Project Cost** ($)	**Net Life Cycle Benefit**[2] ($)	**Simple Payback Period**[3] (yrs)
B-1 Pump Off-peak	0	1,570	$51,200	$0	$92,600	Immediate
B-2 Install Transformer and Receive Power at Primary Voltage[4]	0	0	$28,000	Not Estimated	$50,900	
B-3 Operate Emergency Generator to Avoid Peak Demand Charges[5]	0	785	$18,700	$0	$33,800	Immediate
TOTAL	**0**	**1,570**	**$97,900**	**$0**	**$126,400**	

1 Annual savings are calculated at current rates. Electricity rates are expected to decline by 20% to 25% in the next 3 to 4 years when the Customer Transition Charge expires.
2 Net Life Cycle Benefit = Present Value of Annual Savings – Project Cost. A measured life of 2 years is assumed, corresponding to the period until the Customer Transition Charge is expected to expire and rates are expected to decline.
3 Simple Payback Period = Estimated Project Cost/Annual Monetary Savings.
4 Savings are calculated assuming the off-peak pumping recommendation is implemented.
5 Savings are calculated assuming unavoidable peak period operation is required for 2 months during the year. Existing E20S rates are used due to the uncertainty of implementing the recommendation to install a transformer and receive power under E20P rates.

SCOPE OF WORK

This report is the result of a feasibility energy audit to provide a more detailed analysis of the potential energy efficiency measures that were identified in the preliminary energy audit. The scope of this project mainly includes process equipment, such as pumps and motors.

The measures identified in the preliminary site survey that were selected for further investigation in this report include the following.

- Pump Off-peak

In addition, during discussions with BEC and WST staff regarding the scope of this study, two additional projects that might reduce energy costs were identified.

- Install Transformer and Receive Power at Primary Voltage
- Operate Emergency Generator to Avoid Peak Period Demand Charges

An analysis of these two measures is included in this report.

SITE DESCRIPTION

The Baden Pumping Station consists of three pumps. Two pumps are rated for 13,500 gpm at 225 feet of head pressure, driven by 1,000 hp electric induction motors. The third pump is rated for 9,700 gpm at 225 feet of head, driven by a 700 hp electric synchronous motor. The pumps are currently operated as needed to deliver water from the Hetch Hetchy supply to the clean water reservoir at the Harry Tracy Water Treatment Plant and other reservoirs in the City. They are also operated periodically for a few hours to maintain them in good working order.

HISTORICAL ENERGY USE

This site uses approximately 1,400,000 kWh of electricity per year, with a demand range of 800 to 1,800 kW per month. The total annual utility cost is approximately $287,000, charged at the PG&E E20S rate. This results in a very high average cost of $0.21 per kWh, including demand charges. This high cost per kWh is the result of the significant annual demand charges that are incurred in proportion to the relatively low annual energy use.

The pumping station has historically recorded a very poor power factor, averaging 56%. Investigation of measures to improve the power factor is ongoing. In order to avoid delay in issuing this draft report, the results of this investigation are not included but will be incorporated in the final version of this report.

An overview of historical energy use at this site is provided in Appendix B. The data provided covers the most recent 12-month period for which data are available, October 1998 through September 1999.

POTENTIAL PROJECTS

Pump Off-peak

The pumps at the Baden Pumping Station are currently operated intermittently as needed without consideration for the time of day. Historical operation has ranged from 3 to 230 hours per month. Because the pumping station is billed on a time-of-use electricity rate schedule, significant cost savings can be achieved if operation of the pumps were avoided during the peak period.

The PG&E E20S rate schedule defines the peak period as noon to 6:00 p.m., Mondays through Fridays, May through October. The demand charge during this period is $13.35/kW. In comparison, the demand charge for the part-peak period is $3.70/kW. There are 600 hours per month that are not peak-period hours. Given the recent historical operation of less than 250 hours per month, it appears that all of the typical pump operation can be shifted to part-peak and off-peak hours.

This is further supported by a more detailed review of the distribution of energy use across the peak, part-peak and off-peak billing periods. Currently, the majority of the hours that the pumps are operated already occur during the off-peak and part-peak hours. The pumps were operated for only 28 hours during the peak-period, which is 3% of the total annual operating hours of 803. The highest number of hours that the pumps were operated during the peak period for any month was 17.5 in September 1999. Shifting operation of this small number of hours from the peak-period to part- and off-peak periods will not change current operating practices significantly.

Under the current PG&E E20S rate schedule, for each of the two 1,000 hp pumps that is operated during the part-peak period instead of the peak period for an entire summer month, a demand cost of $7,600 will be avoided. If operation of the 700 hp pump is shifted from the peak period to the part-peak period for an entire summer month, a demand cost of $4,400 will be avoided. Additionally, energy cost savings will result from shifting the operation from on-peak hours to part-peak hours. The energy cost during the part-peak period is 33% lower than the cost during on-peak hours. To calculate typical annual savings, the 12-month period from October 1998 through September 1999 was used as a base year. By shifting pump operation to part- and off-peak hours, the potential cost savings are $51,000 per year.

Another energy cost reduction measure recommended in this report would result in a change in the applicable rate schedule for the pumping station from E20S to E20P. The demand charge for the E20P peak period, $11.80/kW, is slightly lower than the E20S peak period demand charge. Under this rate schedule, for each of the two 1,000 hp pumps that is operated during the part-peak period instead of the peak period for an entire summer month, a demand cost of $7,200 will be avoided. If operation of the 700 hp pump is shifted from the peak period to the part-peak period for an entire summer month, a demand cost of $4,200 will be avoided. By shifting pump operation to part- and off-peak hours, the potential cost savings are $48,000 per year.

At the time that this report was produced, the California Public Utilities Commission (CPUC) was reviewing proposed rate changes that will go into effect at the end of the current rate freeze. The end of the rate freeze will occur on March 31, 2002 at the latest, but may occur sooner. The E20 rate schedule proposed by PG&E no longer includes a time-of-use demand charge, only a maximum monthly demand charge. The proposed demand charges are $9.05/kW during the summer and $2.06/kW during the winter. These demand charges are the same for both the E20S and E20P rate schedules. This maximum monthly demand charge will be incurred regardless of the time of day it occurs. Therefore, avoiding operation during the peak period hours will no longer result in demand cost savings, only small energy cost savings. Using the 12-month period from October 1998 through September 1999 as a base year, the energy savings are approximately $600 per year for the proposed E20S and E20P rate schedules.

The results from each of these four different rate schedules are summarized in Table 5.2. Refer to Appendix C for detailed calculations.

TABLE 5.2 OFF-PEAK PUMPING AVOIDED DEMAND COST ($/mo)

	Avoided Demand Cost ($/mo)			
	Existing Rates		Proposed Rates	
Pump hp	**E20S**	**E20P**	**E20S**	**E20P**
1000	$7,600	$7,200	$0	$0
700	$4,400	$4,200	$0	$0

The actual rates and structure of the rate schedules will not be determined until the CPUC decides on the pending rate case. Elimination of the time-of-use demand charge is not a certainty, but the current PG&E proposal does not include this charge.

Install Transformer and Receive Power at Primary Voltage

The pumping station currently receives power at secondary voltage and is billed under PG&E's E20S rate schedule. The PG&E E20 rate schedule includes lower demand and energy rates for customers that receive power at primary voltage, which are called E20P rates. In order for the pumping station to use power at the primary voltage exclusively and thus take advantage of the E20P rates, the WST department would need to own and maintain the transformer that converts the voltage from primary to secondary voltage. According to station maintenance personnel, there is an existing transformer at the station that is owned by PG&E. The department could either negotiate with PG&E to purchase this transformer, or install a new transformer.

Under the current PG&E E20 rate schedule, receiving power at primary voltage rather than secondary will result in annual cost savings of $38,000. This number is based on the 12-month period from October 1998 through September 1999 as the base year, reflecting current operating practices. If the WST department adopts the recommended procedure to avoid on-peak pumping, the cost savings from receiving power at primary voltage will be $28,000.

As mentioned in the discussion of the off-peak pumping project, PG&E has proposed changes to the E20 rate schedule that are currently under consideration by the CPUC. Under the proposed rates, the demand charge is the same for both secondary and primary voltage. The proposed energy charge for power received at primary voltage is lower than for power received at secondary voltage, however, the proposed discount is much smaller than under the current rate schedule. Under the proposed PG&E E20 rate schedule, receiving power at primary voltage rather than secondary will result in annual cost savings of $12,000 under current operating practices. If the WST department adopts the recommended procedure to avoid on-peak pumping, the cost savings from receiving power at primary voltage will be $11,000.

The results from each of these four different rate schedules are summarized in Table 5.3. Refer to Appendix A for detailed calculations.

TABLE 5.3 E20P VS. E20S ANNUAL ENERGY SAVINGS ($/year)

	Annual Energy Savings	
Operating Scenario	**Existing Rates**	**Proposed Rats**
Current Operation	$38,000	$12,000
No on-peak operation	$28,000	$11,000

The City has performed a preliminary analysis of this project. The scope of this study is limited to refining the estimated cost savings associated with implementation of this project. Determination of the feasibility of installing a new transformer and preparation of a cost estimate are not included.

Operate Emergency Generator to Avoid Peak Period Demand Charges

The WST department has recently installed an emergency generator at the Baden Pumping Station. According to the nameplate data, the diesel generator is a Caterpillar, Model 3516, rated at 1530 kW.

The purpose of the emergency generator is to allow operation of the pumping station upon loss of utility power. The generator is started manually when utility power is unavailable and the pumps are required to operate. The generator is intended to be operated intermittently for short periods only.

Staff at the WST department have suggested using the emergency generator to avoid peak period demand charges. Under this scenario, if pumping from the station is required during peak period hours, before starting a pump, the emergency generator would be started. The station would be operated using power from the emergency generator rather than the utility, thereby avoiding the utility demand charge.

Under the existing PG&E E20S rate schedule, if the emergency generator is used for unavoidable peak period operation of one of the 1000 hp pumps for an entire month, a demand cost of $10,500 will be avoided. If the emergency generator is used for unavoidable peak period operation of one of the 700 hp pumps for an entire month, a demand cost of $6,100 will be avoided. Under the existing PG&E E20P rate schedule, if the emergency generator is used for unavoidable peak period operation of one of the 1000 hp pumps for an entire month, a demand cost of $9,300 will be avoided. If the emergency generator is used for unavoidable peak period operation of the 700 hp pump for an entire month, a demand cost of $5,400 will be avoided. The cost of the fuel for operating the emergency generator is approximately $60 per hour. Under any reasonable temporary period of generator operation, the demand cost savings will be much larger than the fuel cost. See Appendix A for detailed calculations. The results from these different rate schedules are summarized in Table 5.4. Refer to Appendix A for detailed calculations.

TABLE 5.4 AVOIDED DEMAND COST BY OPERATING EMERGENCY GENERATOR ($/mo)

Pump hp	Avoided Demand Cost ($/mo)	
	E20S	**E20P**
1000	$10,500	$9,300
700	$6,100	$5,400

The avoided demand costs for this recommendation are greater than those for the off-peak pumping recommendation because it is assumed that operation of the pumps during the peak hours is unavoidable and cannot be shifted to part-peak hours. Therefore, under the E20S rate schedule the avoided demand cost is $13.35/kW, rather than $9.65/kW, the difference between the on-peak and part-peak demand cost, for the off-peak pumping analysis. Similarly, under the E20P rate schedule the avoided demand cost is $11.80/kW, rather than $9.15/kW.

Under normal operating conditions, avoiding the demand charges by shifting operation to non-peak periods as described in Section 3.3.1 is preferred. However, if operation of the pumping station during the peak period is unavoidable, using the emergency generator to avoid peak demand charges is a viable solution.

There are limitations to this scenario due to air quality regulations. The Bay Area Air Quality Management District (BAAQMD) has jurisdiction over emissions from the generator. According to regulation 2-1-113.2.10, a standby internal combustion engine can be operated on a temporary basis for up to 30 days per calendar year without a permit. If the engine is operated more than 30 days, it is no longer exempt from the permitting requirements of Section 2-1-302. A copy of the regulation is included in Appendix D.

The kW draw is approximately 785 kW for each of the 1000 hp pumps and 460 kW for the 700 hp pump. Operating both 1000 hp pumps simultaneously would require approximately 1570 kW, which slightly exceeds the capacity of the generator. Therefore, when the station is being powered by the emergency generator, operation should be limited to one of the 1000 hp pumps or one 1000 hp pump and the 700 hp pump.

As mentioned in the discussion of the previous projects, PG&E has proposed changes to the E20 rate schedule that are currently under consideration by the CPUC. The E20 rate schedule proposed by PG&E no longer includes a time-of-use demand charge, only a maximum monthly demand charge of $9.05/kW during the summer and $2.06/kW in the winter. Therefore, if these proposed changes are approved, there will be no peak period demand cost savings and no monetary incentive to operate the emergency generator for unavoidable peak-period operation of the pumps.

OPERATING INSTRUCTIONS

Based on the analyses included in this report, there are several opportunities to reduce the operating costs at the Baden Pumping Station. Some of these recommendations involve modifications to the operation of the pumps and include new pumping strategies. Draft versions of flowcharts detailing the recommended operating strategies for the pump station are included in Appendix E. Flowcharts are provided for three different scenarios.

- Normal Operation of HTWTP
- Shutdown of HTWTP
- Power Outage at HTWTP

These flowcharts were developed to reduce operating costs based on the findings in this report. An analysis of the effect of these modifications indicates that adequate performance will be maintained and this was confirmed in discussions with operating personnel.

The flowcharts are preliminary and are intended to provide a starting point for development of final operating procedures that are acceptable to the WST operating staff and that meet the department's operational requirements. A detailed review and critique by the WST operating staff is required to further develop the operating procedures. In particular, the draft procedures presented in this report use the level in the clean water reservoir as the criterion to initiate operation of the Baden pumps. Feedback from the WST staff is needed to assess the acceptability of using the clean water reservoir level as the operating criterion and to determine the specific level setpoint.

Limitations of Baden Study

This report is the result of a feasibility energy study to provide more detailed analysis of potential energy efficiency measures that were identified during the preliminary site survey. The best methods of accomplishing the recommended projects or variations thereof should be determined during the design process. This study does not include specific design instructions. It is not intended as a design document and projects have not been developed to design level. The design professional or other persons following the recommendations herein shall accept responsibility and liability for the results.

CONSULTANT'S REVIEW OF THE OLIVIA CHEN REPORT

Scope of Work

As part of the energy evaluation of the Harry Tracy Water Treatment Plant, the City of San Francisco has asked HDR to review and comment on the Ozonation Process Evaluation Improvements Project - Phase 1 report. The findings of this project were presented in a report by Olivia Chen Consultants, Inc. (OCC) dated December 1998. The City has asked HDR to review the report and document it in an user friendly summary report including which strategies were evaluated, and conclusions reached in the report. HDR was also asked to identify any remaining energy related questions that could follow up from the report. The purpose of the review and evaluation was to ensure that the City was able to monitor the Harry Tracy Water Treatment Plant ozone power consumption better in both real time and trended information. It is HDR's understanding that the work done for the report was intensive and required considerable time and effort by the consultants and the plant field staff.

System Description

The ozonation system was installed in 1992 and feeds ozone to the raw water. The ozone system has three generators with a total capacity of 1,088 lbs/day of ozone using an air source, and a capacity of 2,176 lbs/day of ozone using liquid oxygen (LOX). A schematic diagram of the ozone system is shown in Figure 6-1. The capacities listed above are with two units operating and one unit on stand-by.

The feed gas system provides a clean, dried, and compressed air for normal operation with augmentation of liquid oxygen feed for extreme demands. The air preparation system includes air compressors, after coolers, air receivers, refrigerated dryers, and desiccant dryers. The feed gas preparation system uses nearly half of the energy for the ozone system.

By today's standards the design of the ozone generators is obsolete. Despite the age and condition of the equipment the overall energy performance is acceptable. The facility runs with specific energy ranging from 11 to 14 kWh per pound of ozone produced depending on the production rate. The highest specific unit energy consumption observed at the lower ozone production rates. The best specific energy rates are produced at near capacity.

Fig 6-1

Summary of Findings of the Olivia Chen Report

The objective of the work performed by Olivia Chen Consultants, Inc. was to develop a comprehensive improvement and optimization plan for the ozonation system at the Harry Tracy Water Treatment Plant. Their work included:

1. Completing a thorough investigation and assessment of the existing ozone system, its operation, and identified problems and issues.
2. Identifying physical and operational deficiencies.
3. Recommending short term and long term physical improvements and operational modifications and preparing a report documenting the evaluation, its findings, and recommendations.

The final report was dated December 1998. A team of expert consultants was selected to be part of the team to prepare this report. The expert consultants were, Bill Belamy of CH_2M Hill, Inc., Mike Price from Montgomery Watson, and Kerwin Rakness of Process Applications, Inc. This group is well known for their expertise on ozonation issues. HDR's understanding of Process Applications, Inc. is that are the nation's premier consultant for ozone system evaluation and conceptual design.

The above investigators were asked to classify the problems and issues under three categories:

- Existing problems.
- Design issues and questions.
- Operational issues and questions.

A summary of the recommendations made in the OCC report is presented in Table 6-1. The recommendations identify physical improvements, operational modifications, and additional testing and studies needed.

HDR Comments on the Olivia Chen Report

The Olivia Chen Consultants, Inc. 1998 report provides an excellent process review of the Harry Tracy WTP ozone system. It evaluates existing problems, design issues, and operational issues with a strong emphasis on energy. In summary, the report suggests that with minor exceptions, the ozone facility is considered to be optimized for energy efficiency. We agree. Two significant energy optimization ideas were identified in the report:

1. Use a single air compressor and do not run a standby unit in the unloaded mode. This suggestion apparently has been implemented.

Table 6-1 Olivia Chen Consultants Report Summary of Recommendations

ISSUE	RECOMMENDATIONS		
	PHYSICAL IMPROVEMENTS	**OPERATIONAL MODIFICATIONS**	**ADDITIONAL TESTING AND STUDIES**
Existing Problems			
E1: Uneven Flow Distribution Between Basins	▪ Provide adjustable inlet gates. ▪ Provide gate actuators and monitoring systems. ▪ Structurally modify the inlet structure by modifying the overflow structure.	▪ Establish control logic to regulate flow through inlet gates.	▪ Consult with gate manufacturer to determine if gates are suitable for flow control. ▪ Conduct structural and hydraulic evaluations to assess feasibility of modifying the inlet structure.
E2: Corrosion in the Open Loop Ozone Cooling System	▪ Convert the open-loop system used to cool the air preparation and ozone generation system to a closed-loop system using either raw water or filtered water from the backwash tank. ▪ Replace steel cooling water pipe with PVC pipe.		Conduct feasibility study to determine whether raw water or filtered water from the backwash tank should be utilized for the closed-loop cooling system.
E3: Cooling System Pumps Loose Suction	▪ Convert the open-loop system to a closed-loop system using either raw water or filtered water from the backwash tank as described in recommendations for Issue E2.		See recommendations for E2.
E4: Cracking and Leaking of Cooling System Power Supply Unit Hoses	▪ Replace power supply unit hoses of a more suitable material, such as Teflon or stainless steel.	▪ If the existing hoses are continued to be used, increase the frequency of hose replacement and include them on the plant's Preventive Maintenance Schedule.	
E5: Failures Related to Ozone Off-Gas Destruction System		▪ The blower cycling should be corrected by reprogramming the control system to increase the dead band and dampen the control response. ▪ The current temperature differential setting should be maintained at a value to prevent any condensation.	
Design Issues			
D1: Adequacy of ozone Diffuser System	▪ If the plant switches to high-concentration oxygen generation, may want to replace existing rod diffusers with a shorter rod-shaped diffuser, such as 12 or 18 inch.		
D2: Feasibility of Ozone Off-Gas Recycling	▪ Off-gas recycling is not recommended.		
D3: Power Supply Unit Useful Life	▪ Replace existing PSUs only when the existing ones become inoperable or inefficient.	▪ Maintain existing PSUs as long as economically feasible.	
D4: Addition of a new Ozone Generator	▪ When the plant is to be expanded, add a high concentration oxygen-only generator and make it the primary generator; also consider on-site high concentration oxygen production and converting the entire system to LOX.		▪ Evaluate whether one new 1,000 ppd generator, or two new 500 ppd generators, is preferred during the preliminary design phase of the plant expansion.
Operational Issues			
O1: Optimization of Ozone Generation System:	▪ Consideration should be given to installing VFDs on air compressors, depending on degree of optimization that can be gained using existing equipment (see recommended Operational Modifications), in order to reduce compressor power demand.	▪ The plant flow meters should be recalibrated; a smaller orifice plate may need to be installed to provide more accuracy at current operating gas flow rates. ▪ Consideration should be given to operating one air compressor at reduced pressure, if operationally feasible, in order to lower power requirements. ▪ Over the next several months the plant staff should operate in both air-fed and LOX-oxygen-fed modes to develop a cost comparison database using the ozone data monitoring program developed as part of the ozone optimization project.	▪ The SFPUC should pursue DOHS approval for the log-integration method for CT value calculation in order to minimize the number of ozone residual measurements and obtain full credit in the ozone contactor for *Giardia* cyst inactivation.
O2: Ozone Application in Multiple Cell		▪ Continue adding ozone in only the first cell of each contactor.	
O3: One Contactor at High Flow vs. Two at Low Flow		▪ At high water temperatures (say 20°C), operate the fewest number of contactors based on flow requirements. ▪ At low water temperatures (say 10°C), the fewest number of contactors should be placed in service as long as the *Giardia* cyst inactivation credit goal is reached without problematic ozone residuals at the outlet of Cell 5.	
O4: CT Calculation Spreadsheet			▪ See recommendation for Operational Issue 1 above.
O5: Increase of T_{10}/T Factor			▪ No additional tracer tests are recommended at this time.

2. Provide a variable speed drive unit for one more air compressor. It was also suggested that the discharge air pressure be optimized. The changes have not been made.

It does not appear that any other significant energy optimization ideas are practical for the Harry Tracy WTP ozone facility without replacement of the generators with modern more efficient equipment. Other modifications are unnecessary because the plant may be expanded within 5 years. At that time more efficient equipment would be installed and allowing the existing equipment to be used for standby or peak flow conditions.

The data monitoring program developed and implemented in October 1998 is impressive. It provides an excellent summary of performance. Harry Brown has provided much of the input on the program. Some of the spreadsheets developed for the program are included in Appendix __. We will limit our comments on the monitoring program to energy related items. Process issues are beyond the scope of our investigation. The energy data collected in the program is desirable. However, the cost of data acquisition and the usefulness of the data must be considered. The energy monitoring program will not identify new optimization ideas; it will simply allow plant staff to monitor unit energy consumption so that changes in efficiency can be investigated. Data acquisition should be done automatically from SCADA, but a certain amount of manual input could be justified. Data acquisition need not be daily. Weekly or monthly data input may suffice. We suggest using the items in Table 6-2 to monitor the ozone system if the Phase 2 monitoring program is implemented. Many of these items (such as kW transducers) have a capital cost. We are not convinced that the cost and complexity of the Phase 2 monitoring program is practical.

Table 6-2 HDR Suggests Phase 2 Monitoring Parameters for the Harry Tracy WTP Ozone System

Parameter		Unit	Calculated Value	Display	Comments
1	Flow	Mgd		Plot	
2	Generator Power (all units)	kW		Plot	
3	Generator Power	KWh/day			
4	Total O_3 Production	Lbs/day			
5	Generator Unit Energy		kWh/lbO_3	Plot	Alarm if outside prescribed limits
6	Total O_3 System Power	kW		Plot	
7	Total O_3 System Power	KWh/day			
8	Total O_3 System Unit Power		kWh/lbO_3	Plot	Alarm if outside prescribed limits
9	LOX Use	lbs/month			
10	LOX Cost	$/lb		Plot	
11	Unit Cost of LOX Use		$/lb$O_3$	Plot	
12	Air Prep Energy (Compressors and Dryers)	kW			
13	Air Prep Energy	KWh/day			
14	Air Prep Unit Energy		kWh/lbO_3	Plot	
15	Air Prep Unit Energy Cost		$/lb$O_3$	Plot	

16	LOX and Air Prep Cost	$/lbO$_3$		Plot	

HDR'S Comments on OCC Report

The comments listed below come from a review of the OCC report and HDR data on the energy consumption of ozone systems. The source of information is listed after each comment.

1. Existing ozone system specific energy consumption is reasonable: 14 kWh/lb at 200 lbs/day and 10 kWh of ozone at 1,100 lbs per day (assumes air feed, See Figure 9 on page 21 of OCC report for variation). (Source: OCC Report)
2. Ozone units are over 10 years old and are considered obsolete by today's ozone standards. The units do not appear to be compatible with pure oxygen or 100% LOX feed (Source: HDR).
3. Ozone system appears to use approximately 20% of plant power. Largest energy consumer by far is the raw water pumping station (Source: HDR).
4. Total energy cost for the ozone system is approximately $120,000/year. Even if the ozone system could be optimized to reduce consumption by 20%, the savings would only be $24,000 per year. The labor and material cost of data acquisition, monitoring, and retrofits should be weighed against the potential savings. The energy cost and potential savings for the raw water pumping station are nearly four times the ozone system (Source: HDR).
5. Ozone process improvement study was conducted by Olivia Chen Consultants, Inc. in 1998. It appears that a significant contributor to the study was Process Applications, Inc., with direct involvement by Kerwin Rakness. We consider Process Applications, Inc. to be the country's premier ozone process specialists.
6. The plant normally operates at approximately 50 mgd, with peaks up to 90 mgd. If other City water sources are interrupted, flows of up to 125 can be required. A recent plant expansion increased hydraulic capacity to 180 mgd, although DHS limits the capacity to 140 mgd (Source: OCC Report).
7. Three ozone units are installed. Using air as the source of the generators, the plant can treat 90 mgd with two units operating (one standby) at a dose of 1.3 mg/L ozone. For higher flows and ozone concentrations, the air system must be augmented with LOX. The capacity with 100% LOX is 140 mgd at an ozone dose of 1.7 mg/L (Source: OCC Report).
8. LOX prices have been dropping, current cost is ______ (Source: HDR).
9. At an anticipated energy cost of $0.05/kWh it appears that LOX usage is practical if LOX is less than $30 per ton (HDR). This assumes LOX produces a 5% O_3 concentration.
10. Expansion of the ozone system by 50% (to 3,000 lbs/day) is anticipated. The strategy proposed in the Olivia Chen Consultants, Inc. report is to use new oxygen fed ozone unit(s) normally, and utilize the existing units only during peak demand conditions (Source: OCC Report).
11. Optimization of the air compressor operation appears to have the greatest energy saving potential (Source: OCC Report and HDR).
12. Lights in the ozone building appear to be on 24 hours/day. Personal sensors could produce considerable savings (Source: HDR).

13. It appears that any energy optimization ideas must have a simple payback of 5 years or less if the new generators are to be on-line by 2005 (Source: HDR).
14. An ozone data monitoring program was implemented in October 1998. The goal of the program was to develop reports that would allow plant staff to assess cost benefit of charges made to the ozone systems. Sample data entry forms provide a great deal of information about the ozone system performance. They are shown in OCC report.
15. Specific energy of the ozone generator (without air preparation energy) ranged from 8.5 kWh/lb to 10 kWh/lb during the period of 10/98 to 4/99. These values are higher than expected (7.5 kWh/lb) due to inaccurate ozone meters (Source: Report).
16. Olivia Chen Consultants, Inc. considers the existing ozone system to be optimized (Olivia Chen letter to Julie Labonte dated June 1, 1999 with attachment by Process Applications, Inc. dated May 27, 1999). HDR believes the existing ozone system would be considered optimized if modifications (VFDs) are made to the air compressors.

HDR's Recommendations

1. Minimize labor associated with ozone data monitoring (energy related) because the ozone system is sufficiently optimized.
2. When the plant and ozone system are expanded, use existing equipment as backup.
3. Install a VFD on one or two air compressors.
4. Minimize the use of LOX if the cost is over $30/ton.
5. Implement a modest energy monitoring program that targets two parameters:

   - kWh/lbO_3 for O_3 generation system.

   - kWh/lbO_3 for total O_3 system.
6. Install personnel sensors for fluorescent lighting systems in the ozone facility.

The purpose of monitoring ozone efficiency is to track two key parameters, kWh/lbO_3 for ozone generators and the total ozone system variations from the target range. These parameters will help to identify malfunctioning components or flow measurement devices.

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